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METAL SHEET FOR BUILDING PURPOSES, AND METHOD AND APPARATUS FOR MAKING SUCH SHEETS

The invention relates to a metal sheet for building purposes, comprising a panel and two standing flanges lengthwise at opposite sides of the panel. The invention also relates to a method and an apparatus for making such sheets.

Metal sheets of this kind are well known and used in the construction of many buildings, and especially the roofs thereof. The longitudinal sides of the metal sheets are bent upwards to form two opposite flanges, so as to form standing seams which are formed from one flange of one panel and the opposite flange of the neighbouring panel. For ease of forming the standing seams, the free ends of the flanges are often themselves flanged to be able to cooperate with each other and to be able to cooperate with holding elements for holding the roof or wall. The sheets normally have a length between approximately 1 to 100 meter, often about 10 metres or more, and a width that can vary between for instance 100 and 2000 millimetre, mostly about 500 millimetre.

Most panels that are used for building purposes are rectangular sheets, which can be used for straight or curved roofs. Curving of metal sheets is known from for instance EP-A-1.138.403.

However, modern buildings are often designed with more complex forms, such as conical roofs. For the construction of conical roofs tapered panels have to be used. The forming of tapered sheets and the forming of flanges on a tapered sheet is known from for instance EP-A-1.138.424 and EP-A-1.138.405. The conicity of the tapered sheets can be given by a width of at least 140 mm at one end and a width of at most 1000 mm at the other end of the panel, but other widths are possible.

It is a first object of the invention to provide a metal sheet with standing flanges for building purposes, which can be used for buildings with other forms.

It is a second object of the invention to provide a method for forming such a metal sheet.

It is a third object of the invention to provide an apparatus for forming such a metal sheet.

According to a first aspect of the invention, the first object of the invention is achieved with a metal sheet for building purposes, comprising a panel and two

standing flanges lengthwise at opposite sides of the panel, wherein one or both flanges have a non-rectilinear form in the plane of the panel.

Due to the non-rectilinear form of the flanges, it is possible to construct all types of complex forms of roofs or walls of buildings, for instance a roof that is slightly dome-shaped. For this situation, preferably metal sheets are used where one or both flanges have an essentially convex form. Such sheets having a convex form are less wide at their ends than they would have been when the flanges would have been straight. For both these examples, essentially rectangular sheets which are convex can be used.

According to another preferred embodiment, the metal sheet has one or both flanges that have an essential concave form. A metal sheet having a concave form is less wide halfway its length than it would have been when the flanges would have been straight. Essentially rectangular sheets which are concave can be used for a roof that is for instance wider at its ends than at the middle, or for other such roofs.

It has to be noted that a panel with flanges having a non-rectilinear form can have other forms than a convex or concave form. It is for instance possible that the flanges have an S-form, if that is needed for the construction of a roof or wall, or that a metal sheet has one flange with a convex form and one flange with a concave form, so the sheet is curved as a whole in its plane.

Preferably, the panel contains one or more corrugations essentially parallel to one or both of the flanges, which corrugation or corrugations give the flange or flanges the non-rectilinear form. Due to the corrugation or corrugations, an extra length of the sheet is taken up as seen over the width of the sheet. Starting from a metal sheet with straight standing flanges, the width of the panel is restricted at the place where a corrugation or corrugations exist. Due to the corrugation or corrugations the flanges thus get their non-rectilinear form.

Preferably, when the flanges have an essentially convex form, a corrugation or corrugations are present in the portion of the panel at the end or the ends of the length of the sheet, and when the flanges have an essentially concave form, a corrugation or corrugations are present in the portion of the panel essentially halfway along the length of the sheet. In this way at least one corrugation is present in that

portion of the panel where it is necessary for it to be in order to obtain the desired convex or concave form.

According to a preferred embodiment, the sheet is an essentially tapered sheet. With such sheets it is possible to form for example conical roofs that are not straight but slightly dome-shaped or contracted halfway their height.

A preferred embodiment for the metal sheet exists where the sheet is a curved sheet. This curvature exists in a plane perpendicular to the plane of the panel. With such curved sheets it is for example possible to form a domed roof which is strongly curved in one direction and slightly curved in the other direction.

According to a second aspect of the invention, the second object of the invention is achieved with a method for forming a metal sheet for building purposes, the sheet comprising a panel and two standing flanges lengthwise at opposite sides of the panel, the method comprising the step of forming one or more corrugations in the panel essentially parallel to one or both of the flanges so as to give one or both of the flanges a non-rectilinear form in the plane of the panel.

Using this method, a metal sheet comprising a panel and two standing flanges wherein one or both flanges have a non-rectilinear form in the plane of the panel is obtained, when starting from a sheet having rectilinear flanges. Sheets having rectilinear flanges are commonly known in the art. The non-rectilinear form is introduced by the forming of one or more corrugations in the panel. Where a corrugation is formed, an extra length of the panel is taken up as seen over the width of the panel, so the panel and thus the sheet will become narrower there. Of course it would be possible to form corrugations in a sheet having non-rectilinear flanges and a flat panel, and to alter the shape of the non-rectilinear flanges in this way; however, such sheets having non-rectilinear flanges and a flat panel are not known in the art.

It has to be noted that in the panels that are known in the art, which have straight flanges and which are rectangular or tapered, corrugations are often present. Such corrugations can for instance take up the expansion or contraction of the metal due to temperature differences. However, these known corrugations are present along the full length of the sheets and do not cause any non-rectilinearity of the flanges.

According to a preferred method one or more corrugations are formed over part of the length of the panel. At those places where a corrugation is present, the width

of the panel will become less because the corrugation takes up some of the material. In this way the flanges become non-rectilinear.

Preferably, one or more corrugations are formed having different portions with different heights. Due to the difference in height, a different amount of material will be taken up as seen over the width of the panel. A corrugation with an increasing or decreasing height will thus lead to a gently curved flange, whether convex or concave. This means that according to the invention corrugations that extend over the full length of the sheet, but have different heights at different portions along the length of the sheet, or a continuous changing height, can be used.

According to a preferred method, the corrugation or corrugations are formed by using one or more profiled rolls. The profiled roll or rolls press the corrugation or corrugations into the panel and in that way give the non-rectilinear form to the flanges.

According to a third aspect of the invention, the third object of the invention is achieved with an apparatus for forming a metal sheet for building purposes, the sheet comprising a panel and two standing flanges lengthwise at opposite sides of the panel, the apparatus comprising means for forming one or more corrugations in the panel essentially parallel to a flange, such that the flange gets a non-rectilinear form in the plane of the panel.

With this apparatus, the method according to the second aspect of the invention can be implemented.

Preferably, the apparatus comprises means for aligning the flange of the metal sheet, parallel to which the corrugations have to be formed by the forming means, and more preferably comprises means for driving the sheet through the forming means. The aligning means can for instance consist of three of four roll pairs, between which a flange of the sheet is guided and thus aligned. Near those guiding rolls, a driven roll can be placed to drive the sheet through the forming means. The sheet as a whole can be guided over horizontal guiding rolls.

Preferably, the apparatus comprises means for guiding the flange after the corrugations have been formed by the forming means, and more preferably comprises means for drawing the sheet through the forming means. These guiding means can also consist of horizontal guiding rolls and some roll pairs to guide the

flange of the sheet. In the same way, a driven roll can be present to draw the sheet through the forming means.

According to a preferred embodiment, the forming means comprise one or more rolls having a circular protrusion, where the cross-section of the protrusion essentially corresponds to the cross-section of the corrugation to be formed, and preferably one or more cooperating rolls having a complementary circular recess. Using such rolls will result in corrugations which run parallel to the flange that they are formed alongside. A cooperating pair of rolls, one with a protrusion and one with a recess, will result in a corrugation having the cross-section as desired, without creases being formed. It will be apparent that the form of the cross-section can be chosen as desired (as far as technically feasible when using rolls), since the amount of material taken up by the corrugations depends for the most part on the height of the corrugation.

Preferably the roll or rolls with a circular protrusion are motor driven and more preferably adjustable in height. The rolls with the protrusion have to press the corrugation in the panel and for that reason are preferably motor driven. By making these rolls adjustable in height is will be possible to form corrugations in the panel having a varying height. The cooperating rolls can have a constant height.

Preferably, the rolls are replaceable. In the way the apparatus can be easily adjusted for a sheet for which a different form of the corrugation is desired. Of course it is also possible to change from a roll having one protrusion to form one corrugation, to a roll having two protrusions to form two corrugations at the same time. These protrusions can be different, for instance have a different height, to form different corrugations at the same time.

The invention will be elucidated referring to some exemplary embodiments of metal sheets, an exemplary embodiment of an apparatus, in view of the accompanying drawings.

Figs. 1 to 3 show, not to scale, some different embodiments of the metal sheet according to the invention.

Fig. 4 shows a cross section through the embodiment of figure 3A.

Fig. 5 shows, very schematically, an apparatus according to the invention for forming the metal sheet according to the invention.

Fig. 6 shows, on a larger scale, a cross section through the forming means in the apparatus of figure 5.

Figure 1 schematically shows a top view of an essentially tapered metal sheet according to the invention. In figure 1A, the tapered sheet 1 has a panel 10 and two flanges 11, 12. These flanges are curved inward or concave in the plane of the panel due to the forming of the corrugations 13, 14 near both flange 11 and flange 12. The metal sheet had been formed in a conventional manner, so with two straight flanges on both sides of the panel. The corrugations 13, 14 have been formed in the middle portion of the panel 10, causing this middle portion of the panel to contract and thus giving the sheet the concave shape. Though it is not clearly visible in figure 1, all the corrugations have a declining height over their end portions or over both halves of their lengths from the middle of the panel, causing the smooth curves of the concave flanges.

Figure 1B in the same way shows an essentially tapered metal sheet 2 with a panel 20 and flanges 21 and 22, but in this metal sheet two corrugations 23 have been formed over the full length of the panel 20, and two corrugations 24 in the middle portion of the panel. In this case, the corrugations 23 have declining portions where they are longer than corrugations 24, and the corrugations 24 decline over both halves of their lengths from the middle of the panel.

Figure 2 shows another essentially tapered metal panel according to the invention, but with convex flanges. In figure 2A, the tapered sheet 3 has a panel 30 and two flanges 31, 32. These flanges are curved outward or convex due to the forming of the four corrugations 33 and four corrugations 34, near both flange 31 and flange 32. Here, the corrugations are formed in the end portions of the panel 30, causing the end portions of the panel to contract and thus give the sheet the convex shape. Here too the corrugations have a declining height, but now towards the middle of the panel.

In figure 2B again an essentially tapered metal sheet 4 is shown, having a panel 40 and two flanges 41, 42. In this sheet, four corrugations 43 near the flanges, and two corrugations 44 over the full length of the panel have been formed. The four corrugations 43 have a declining height towards the middle of the panel, and the two corrugations 44 have a declining height towards their middle portion. In this way, the

end portions of the panel are contracted most, and thus the metal sheet is given its convex shape.

Figure 3 shows essentially rectangular metal sheets. Figure 3A shows a metal sheet 5 having a panel 50 and two flanges 51, 52. In the panel corrugations 53, 54 are formed, in the same way and the same place as in sheet 1 of figure 1A. Thus, the sheet 5 gets concave flanges 51, 52. In an analogous way, in figure 3B a sheet 60 having flanges 61, 62 and corrugations 63, 64 is shown, which corrugations are formed in the same way as in sheet 3 of figure 2A. Thus, the sheet 6 is given convex flanges 61, 62.

For sheets 5 and 6 it should be noted that some or all of the corrugations could be present over the total length of the sheet. Moreover, for all sheets the length or the corrugations can be chosen as desired, as can be their inclination, depending on the desired form of the flanges. It will be clear that, besides convex and concave, the flanges can have other forms, such as an S-form, or a form that is partly straight and partly curved. It is also possible that one flange is concave and one flange is convex, so the sheet is curved in total in the plane of the panel.

Figure 4 shows a cross section A-A halfway through sheet 5 as shown in figure 3A, on a larger scale. However, figure 4 could also have been a cross section through sheet 1 or sheet 2, or an end view of sheet 3, 4 or 6. Figure 4 shows the panel 50 with flanges 51, 52 and corrugations 53, 54. The flanges 51, 52 have a preferred form, such that the flange 52 of one sheet can cooperate with the flange 51 of a neighbouring sheet. However, other flange forms are possible.

In the figures 1-4 sheets having four corrugations are shown. However, it will be possible to use less or more corrugations, depending on the amount of contraction that is desired. For four corrugations, the maximal contraction will be in the order of 10 to 15 millimetre, when the corrugations have a height of approximately 15 millimetre. Of course the corrugations can have another form in cross section, for example be more pointed.

In figure 5 an apparatus for forming the metal sheets according to the invention is shown very schematically and not to scale. Figure 5A shows the apparatus in top view, partially in cross section B-B, and figure 5B in front view. The

apparatus consists of four units, a feed unit 100, a first forming unit 110, a second forming unit 120, and a run out unit 130.

Feed unit 100 has horizontal supporting rolls 101 to support the metal sheet 1, vertical pairs of guiding rolls 102,103 to guide a flange 12 of the metal sheet and feed it in the right position towards the units 110 and 120, and driven rolls 104,105 that feed the metal sheet into the first forming unit 110. Each metal sheet is placed by hand onto the feed unit 100 and guided through the guiding rolls 102, 103, until the driven rolls 104, 105 take over. Of course the feed unit 100 will in most cases be longer than shown in figure 5, since the metal sheets will most times be ten or more metres long.

First forming unit 110 also has supporting rolls 111 to support the metal sheet, and upper forming rolls 112 and lower forming rolls113. As shown, the upper rolls have a circular recess, and the lower rolls have a circular protrusion (not shown). The lower rolls 113 are driven by a driving device (not shown), and the lower rolls 113 are adjustable in height by a height adjusting mechanism (not shown). The upper rolls are fixed in height such that they will roll over the upper surface of the panel of sheet 1, and can rotate freely between brackets 114, which extend from an upper frame 115. As shown, present are three lower and three cooperating upper rolls. However, it would be possible to use less or more rolls, for instance depending on the maximal height of the corrugations to be formed.

Second forming unit 120 is an exact copy of forming unit 110. The parts of this second forming unit will therefore not be described. It would be possible not to use the second forming unit, or to use two of these units, for instance depending on the thickness of the metal of the panel, the type of metal and the number of corrugations to be formed.

Run out unit 130 has supporting rolls 131 as well, and pairs of guiding rolls 132, 133 to guide the flange of the metal sheet after the corrugations have been formed by the forming units 110 and 120. Driven rolls 134, 135 are present to draw the sheet through the forming units, especially after the end of the sheet has left the feed unit 100.

Figure 6 shows a cross section through one of the pairs of upper and lower rolls 112, 113 of first forming unit 110. Shown is also a part of the metal sheet 1

having one corrugation, formed by the upper and lower rolls. The upper roll 112 can rotate freely between the brackets 114 which are fixed to the upper frame 115. The lower roll is releasably attached to a shaft 116, which is driven by a driving device (not shown). The shaft 116 and thus the lower roll 113 is adjustable in height by a height adjusting mechanism (not shown), which is movable in the direction of arrow D. When more than one pair of upper and lower rolls is present, the shafts are coupled to rotate with the same speed and to be moved to the same height.

The lower roll 113 is releasably attached to the shaft, in order to be able to easily exchange one lower roll for another one having a circular protrusion with another cross section. The upper roll will have to be exchanged as well. It will also be possible to use lower rolls having two or even more circular protrusions, and corresponding upper rolls, as long as the material from the metal sheet can flow easily to form the corrugations.

The method of forming corrugations in a metal sheet using the apparatus as described above is essentially as follows. A metal sheet 1 having two straight flanges is placed with its front end on the feed unit 100 and guided through the guiding rolls 102, 103. As soon as the sheet 1 is fed between the driven rolls 104, 105 these rolls take over and feed the metal sheet 1 at a constant speed into the first forming unit 110. The first forming unit 110 contains a detection device (not shown) to detect the front end of the sheet, and a measuring device (not shown), for example a measuring wheel, to measure which portion of the sheet has passed through the forming unit. Based on the signals from the detection device and the measuring device, the height adjusting mechanism will raise or lower the lower roll(s) 113 to form the corrugation in the metal sheet. The height adjusting device will be controlled by a controlling device (not shown) which can be programmed to form the desired corrugations with the desired length and the desired increasing or decreasing height in the sheet. In the same way, the second forming unit 120 can form a second corrugation, or can form the corrugation formed by the first forming unit to a greater height. The run out unit 130 supports the front end of the metal sheet while the corrugations are formed in the back end of the sheet, and draws the sheet through the forming units using the driven rolls 134.

For the person skilled in the art it will be apparent that other designed feed, forming and roll out units can be used, as long as they serve the purpose to form corrugations into metal panels having two flanges at opposite sides of a panel.